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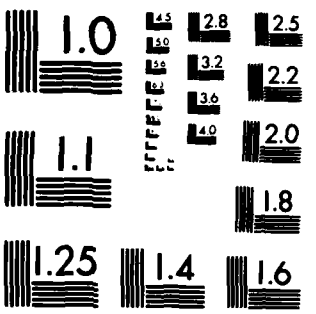

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SPECTRAL AVERAGING AND LOW-FREQUENCY SAMPLING MODIFICATIONS FOR THE IQS 401 FFT SPECTRUM ANALYZER

by

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Prepared for Publication

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by

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ABSTRACT

The IQS 401 spectrum analyzer, a commercial addition to the Apple II and III personal computers, can be modified for low-cost power spectrum measurements of random noise signals and similar waveforms. The IQS BASIC control program is changed to perform low-frequency sampling, spectral averaging and spectrum scaling. External analog filtering must be provided on the lowest sampling rates; however, no change is made to the original IQS hardware. Resolution of 0.5 dB is obtainable from 10^{-4} Hz to 20 kHz.

SPECTRAL AVERAGING AND LOW-FREQUENCY SAMPLING MODIFICATIONS FOR THE IQS 401 FFT SPECTRUM ANALYZER

The IQS 401 FFT spectrum analyzer[1] is a commercial addition to the Apple II and III personal computers. A versatile plug-in hardware card and BASIC control program perform data acquisition, waveform display and spectral analysis. The 401 is well suited for the measurement of repeatable signals such as loudspeaker impulse response testing; however, it has several deficiencies for the analysis of random signals as encountered in electrical noise studies and similar areas. These deficiencies can be corrected to yield an inexpensive power spectrum analyzer capable of measurements extending from 10^{-5} Hz to 20 kHz with 0.5 dB resolution. Approximately 30% of the IQS BASIC control program is changed and external analog filtering is provided. No change is made to the original IQS hardware.

These software modifications enhance the 401's capabilities in three areas: spectral averaging, power spectra scaling and low-frequency sampling.

The unmodified 401 estimates power spectra by computing the Fast Fourier Transform using 128, 256, 512 or 1024 points. The uncertainty in this power spectrum estimate is large; however, it can be reduced by smoothing the spectrum with a moving average digital filter provided in the 401 software. This unavoidably removes the fine details of the spectrum

and may not reduce the uncertainty to an acceptable level. Averaging several independent power spectrum estimates reduces the uncertainty without removing the fine details; however, the original 401 has no provision for this spectral averaging. The software modifications make it possible to rms average 1 to 100 separate spectra. A total of 64 averages results in 0.5 dB resolution when measuring Nyquist noise.

The unmodified 401 displays relative power spectra only. The software modifications calculate a scale factor and adjust the display to correspond to the units of Volts squared per Hertz. This procedure accounts for all related system parameters including sample rate, sample length and amplification.

The unmodified 401 samples at a selectable frequency between 200 Hz and 60 kHz, resulting in a lowest analyzable frequency of 0.2 Hz. The software modifications control the IQS hardware to allow for lower sampling rates. The modifications add seven sampling rates between 10 Hz and 0.01 Hz, resulting in a lowest analyzable frequency of 10^{-5} Hz. Each low-frequency sample is displayed on the computer console screen as it is obtained. This provides early detection of out-of-range errors and other low-frequency data acquisition problems.

The low sampling rates require an analog anti-alias filter external to the computer. An external high-pass filter proves useful in removing DC drift with the low sampling rates. The system shown in Figure 1 has been used for noise studies to 10^{-4} Hz. The analog filters are standard

designs[2] constructed from operational amplifiers. Noise measurements between 0.2 Hz and 20 kHz require only the Princeton Applied Research PAR-113 low noise preamplifier or equivalent.

Figure 2 shows typical power spectra obtained with the system. The input voltage spectral noise density of the PAR-113 and LM-394 preamplifiers is shown together with the observed Nyquist noise of two resistors. This data was obtained by averaging 64 spectra of 256 points at sampling rates of 46 kHz, 1 kHz, 10 Hz and 0.1 Hz. A single sampling rate with 256 points spans about two decades of frequency as shown by the open and filled dated points.

The modified 401's usefulness is limited in some applications by its slowness and limited dynamic range. Approximately 30 minutes is required to calculate a power spectrum from 64 averages of 256 point spectra. The calculation time is limited by the relatively slow 6502 processor used in the Apple II computer. Eight bit analog to digital conversion in the IQS hardware limits the spectral dynamic range to 32 dB.

The ability to adapt this system through software changes makes the 401 an attractive alternative to dedicated power spectrum analyzers costing several times more. Software modifications and filter schematics are available from the author on request. This work was supported in part by the Office of Naval Research.

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FIGURE CAPTIONS

Fig. 1 Typical external filtering for low-frequency sampling.

Fig. 2 Experimental measurements of amplifier noise and Nyquist noise using modified FFT system.

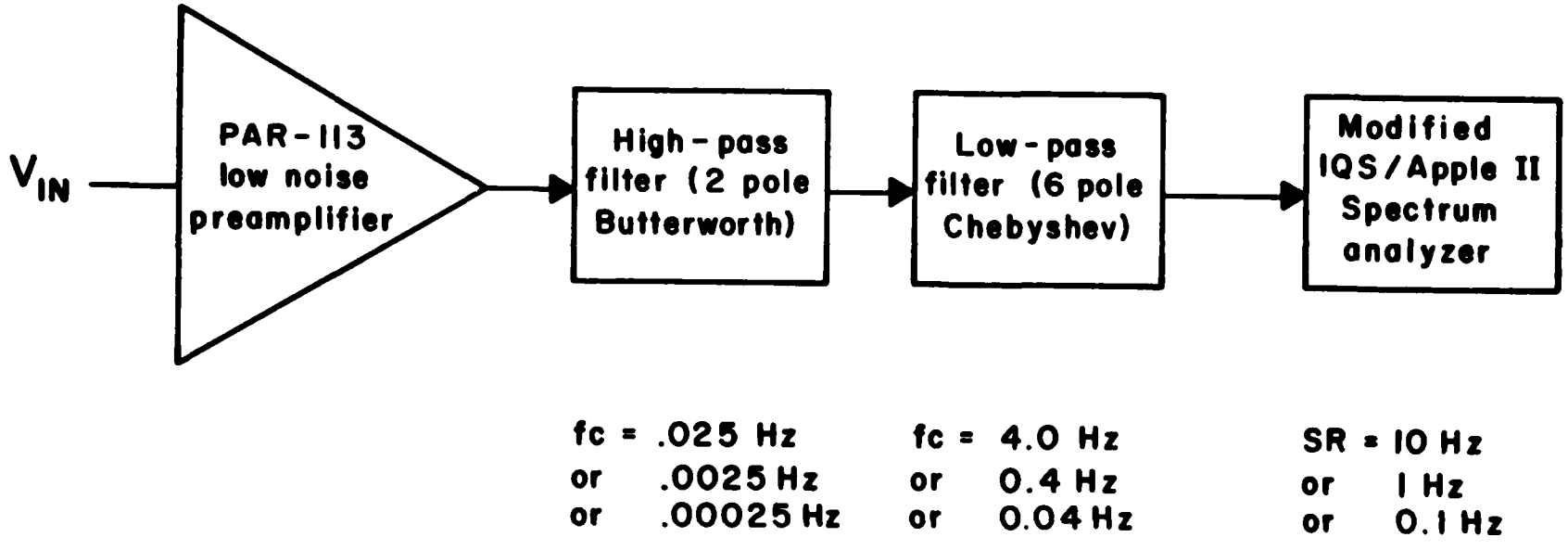

Figure 1. Typical external filtering for low-frequency sampling

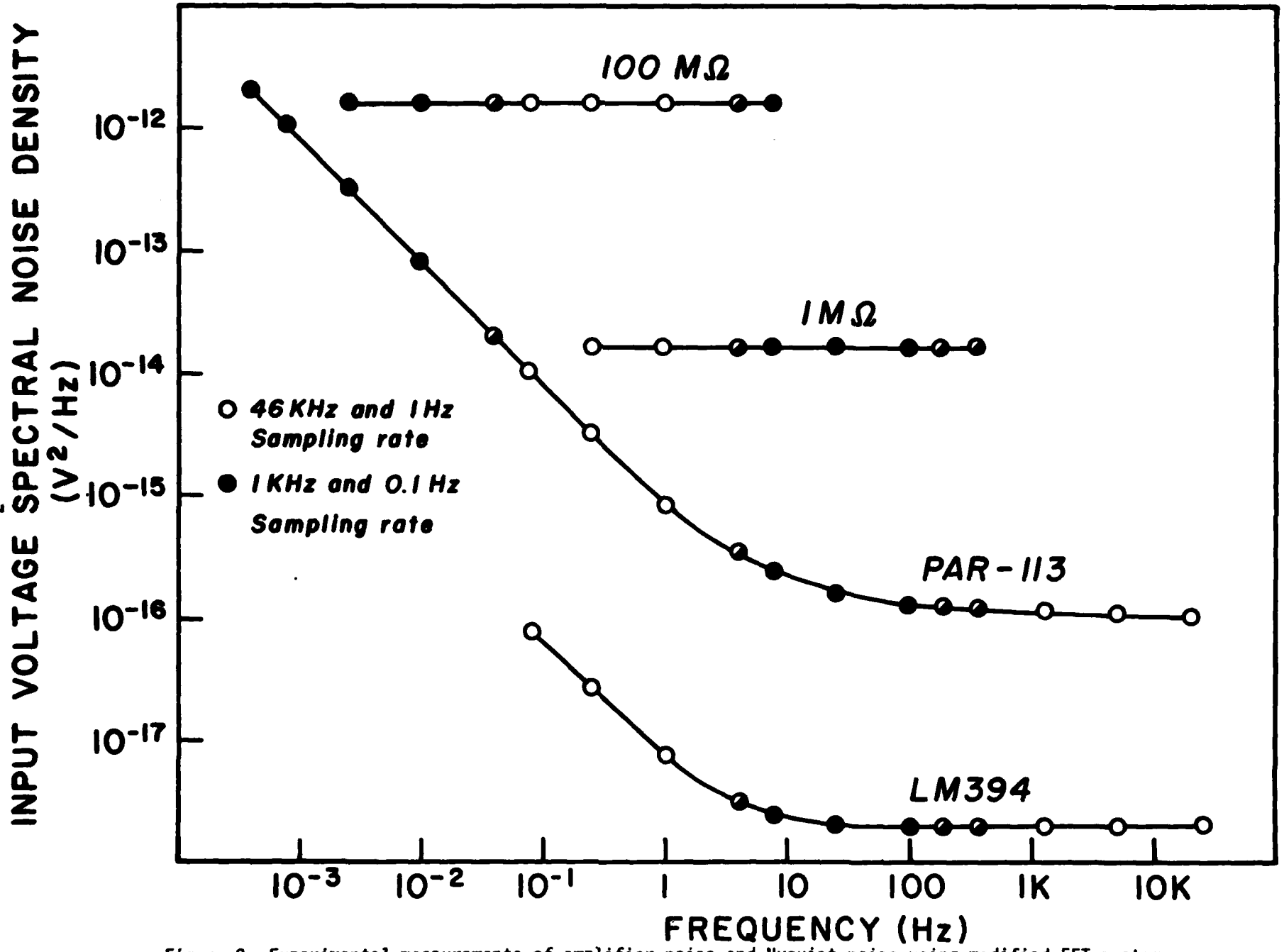

Figure 2. Experimental measurements of amplifier noise and Nyquist noise using modified FFT system.

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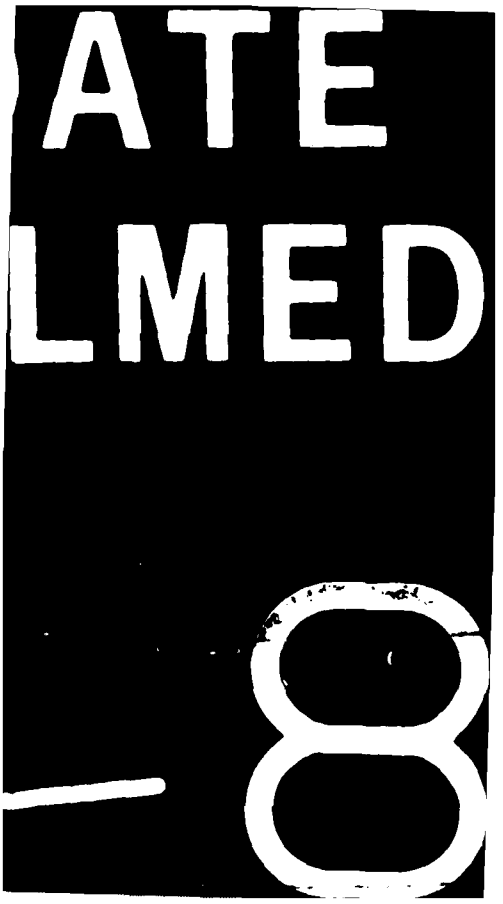
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